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Accelerometer based independent and combined associations of physical activity and sedentary time on physical fitness in preschool children: a cross-sectional study

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To investigate the independent and combined associations between total physical activity (TPA) and sedentary time (ST) using accelerometer on physical fitness in preschool children. A cross-sectional study involving 375 participants (211 boys, and 164 girls) was conducted. Participants were classified as low- or high-active according to the PA guidelines of 180 min/day of TPA and low- or high-sedentary based on the median ST per day. Low active/high sedentary, low active/low sedentary, high active/high sedentary, and high active/low sedentary groups were created. The physical fitness composite Z-score (fitness score) was created from the 20 m shuttle run, musculoskeletal fitness (handgrip and standing long jump), and 2 × 10 m shuttle run tests. Data shown TPA was positively related to the 20 m shuttle run, musculoskeletal fitness, and the fitness score (*P* < 0.05). Regression of TPA on the fitness score was weak (β, 0.01; 95% CI, 0.00, 0.01). The high active/low sedentary Group had the highest odds of higher handgrip strength, musculoskeletal fitness, and fitness score. Classification as high active/low sedentary increased the probability of a high fitness score by 30% (β, 0.30; 95% CI, 0.07, 0.54). Both increasing TPA and reducing ST is essential for promoting physical fitness in this population. The trial registration number is ChiCTR-OOC-15,007,439, and the date of registration is 10/27/2015.

Keywords Sedentary behaviors, ActiGraph GT3X+, Preschooler, Motor fitness, Cardiorespiratory fitness, Muscular fitness

Physical fitness is a vital factor and health marker determining health status in preschool children, which has multiple characteristics, including cardiorespiratory fitness (CRF), musculoskeletal and motor fitness[1]. Previous studies indicate that physical fitness is the foundation of physical activity (PA) and sports performance[2,3], and it plays critical roles in physical health (i.e., metabolic diseases, skeletal health, obesity, and motor capability)[2]. The beginning years of life is a vital window in time to foster physical fitness development, and high levels of physical fitness can facilitate health status in preschool childhood and have critical long-lasting positive effects throughout adulthood[1]. Establishing healthy movement behaviors in early life helped with shaping habits through childhood, adolescence and into adulthood[1,4]. Accordingly, it is of vital importance that physical fitness promotion should be encouraged in the preschool years.

PA is known as a basic factor of healthy lifestyles, and it facilitates CRF, musculoskeletal and motor fitness[2]. Meanwhile, ST is labeled as “spend an energy expenditure of ≤ 1.5 METs at waking time while sitting or reclining”[5]. Results from randomized controlled studies reported preschoolers engaging in higher amounts of PA have higher physical fitness levels[6,7]. Inversely, several studies report that ST is associated with declining physical fitness in

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early childhood[8,9] and predicts poor physical fitness later in adolescence and adulthood[10,11]. Indeed, PA plays a critical role in triggering neurogenesis, synaptogenesis, angiogenesis, and upregulating neurotrophic factors (e.g., BDNF) expression, which enhances the motor performance, and facilitates the development of physical fitness in preschoolers[12]. On the contrary, sedentary behavior may negatively affect physical fitness by damaging brain white matter and reducing motor signal integration and transduction efficiency[13]. Hence, to guarantee the health of preschool children, the World Health Organization recommending that they should accumulated (a) ≥ 180 min/day total physical activity (TPA) (including ≥ 60 min/day moderate-to-vigorous PA), (b) ≤ 1 hour ST at a time (≤ 60 min/day sedentary screen time) and (c) get 10–13 hours of sleep in daily activity guidelines[4]. However, few preschoolers meet the TPA and sedentary behavior guideline. In a sample of 151 Canadian preschoolers, nearly all met the TPA guideline (99.3%), 15.2% met the sedentary behavior guideline, and 15.2% met both the TPA and sedentary behavior recommendation[14]. Similar findings were observed in Belgian preschoolers, whereby < 20% met both TPA and sedentary behavior recommendations[15]. What's more, data shown the adherence in low-income Brazilian preschoolers was only 3%[16] and the prevalence in China was 9.3%[17], which is markedly lower from developed countries. Most preschool children meet the TPA recommendation but spend too much time in sedentary behaviors. Researchers have classified TPA and ST as two constructs that have independent and joint effects on health outcomes, whereby engaging in health-enhancing amounts of TPA may not counteract the deleterious effects of sedentary behaviors on health outcomes[18,19]. An inverse association has been observed between sedentary behaviors and physical fitness in adults[20] and many studies have examined the independent associations of TPA and ST on physical fitness in youth and adolescents[21–24]. Little is known about the joint effects of time spent in TPA and sedentary behaviors on physical fitness in preschool children. As TPA and sedentary behaviors track into adulthood[25,26], it is important to identify the joint associations between TPA and ST and physical fitness.

In preschool children, studies currently usually use caregivers-reported leisure time sedentary behavior such as TV watching and overall screen time, though they may represent substantial parts of ST, they cannot well represent the total amount of ST. Therefore, similarly to PA, devices such as accelerometers based total ST measuring should be applied. They do not rely on participants recall and can capture both daily PA and ST objectively.

The present study's purposes are to investigate the accelerometer based independent and joint associations of TPA and ST on physical fitness characteristics and to examine whether substituting 30 min/day of TPA with 30 min/day of ST is associated with changes in physical fitness. We hypothesized that, participants with high PA and low sedentary level would achieve the highest physical fitness level and substituting 30 min/day of TPA with equivalent ST would be associated with reducing probability of achieving high physical fitness level.

Materials and methods

Study design and participants

We designed a cross-sectional study with 500 preschoolers recruited from 9 preschools in Baoshan and Yangpu Districts of Shanghai, China. A convenience sample was used for feasibility, and the study design, purposes, inclusion criteria, and recruitment procedures are described in a previous study[27]. The inclusion criteria of this study were: (1) children aged 3 to 6 years; (2) healthy, and without cardiorespiratory fitness, neurological or endocrine disease, which may hamper preschoolers to perform the fitness tests[28]. The study protocol was approved by the Ethics Committee of Shanghai University of Sport (Ethics Committee code: 2015028), and it carried out by Declaration of Helsinki and the terms of local legislation. Furthermore, this study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cross-sectional studies[29]. Before starting the study, informed consent was obtained from all participants' parents or their legal representatives.

Initially, we recruited a total of 500 preschool children. Then, we excluded 125 participants for the following reasons: (1) children with a medical disease and unable to perform the fitness tests ($n = 28$); (2) failed to accumulate at least 2 weekdays and 1 weekend day of valid accelerometer wear days ($n = 89$); (3) failed to finish 20mSRT, handgrip, SLJ, and 10mSRT tests ($n = 34$); (4) values being out of the range of SDs ± 3.00 were considered as data outliers ($n = 2$). (Fig. 1). Accordingly, a total of 375 participants were included in the final data analysis, consisting of 211 boys and 164 girls.

Descriptive characteristics

The participant's age and sex were obtained by self-report.

Anthropometric measurements

Four experienced researchers conducted the data collection session in preschools from 09:00 to 11:00 every weekday. Measurements were conducted in groups, and each group made up with eight participants. Other preschoolers who are waiting for measuring were asked to stay in classroom for the regular curriculum. Anthropometric height and weight measurements were taken following the National Physical Fitness Measurement Standards Manual (preschool children's version)[30], and body mass index (BMI) was expressed as kg/m^2.

Physical activity and sedentary time

PA and ST were captured using the ActiGraph GT3X + accelerometers (ActiGraph LLC, Pensacola, FL, USA). These devices are regarded as reliable and valid in measuring PA and ST in young children[31,32]. Children were instructed to wear the accelerometers above the right iliac crista of the hip while awake for 7 consecutive days, excluding water-based activities and bathing. The sampling interval was set at 1s to capture young children's activity characteristics[33]. Sampling frequency was set to the 30 Hz, processed with normal filter and analyzed with

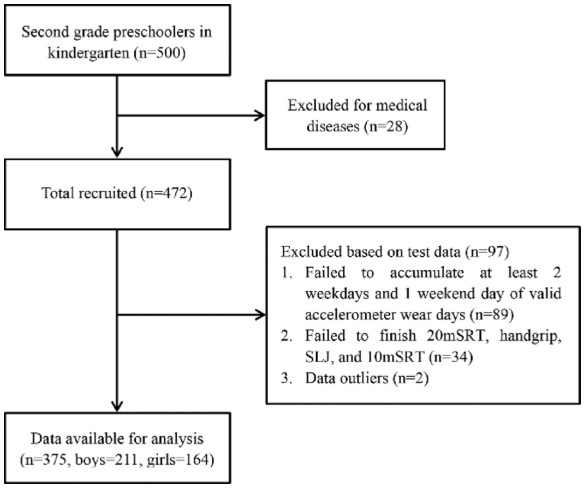

Fig. 1. Flow chat of preschool children in the present study.

vector magnitude as ActiGraph counts[34]. Data were using ActiLife software (version 6.11.5). Valid accelerometer data met the criteria of 8 h/day of wear time with at least 2 weekdays and 1 weekend day for inclusion in data analysis[35]. Periods of more than 20 min of consecutive zero values were classified as "accelerometer not worn" and removed from data analysis by employing the Choi algorithm[36]. Cut-points of TPA, moderate- (MPA), and vigorous-intensity PA (VPA), and moderate-to-vigorous PA (MVPA) were defined as ≥ 100 counts per minute (CPM) for TPA, 1680–3367 CPM for MPA, and ≥ 3368 CPM for VPA and ≥ 1680 CPM for MVPA[37]. ST sampling was no more than 100 CPM, as defined by Evenson[38].

Children were categorized as "low active" or "high active" based on whether they met the Canadian 24-hour PA guidelines of 180 min/day TPA[39] and then stratified the "low active" and "high active" children into boys and girls separately. Regarding ST, children were also categorized as "low sedentary" or "high sedentary" based on the median values for boys and girls[40]. A TPA/ST variable was created by categorizing boys and girls separately into 4 groups. Each group was coded as group 1 = low active/high sedentary, group 2 = low active/low sedentary, group 3 = high active/high sedentary, and group 4 = high active/low sedentary.

Physical fitness

Physical fitness was evaluated by the PREFIT battery[1], which was already validated and widely used by peer publications[27,41,42]: (1) CRF was evaluated by a 20 m shuttle run test (20mSRT)[43]; (2) musculoskeletal fitness was evaluated using the handgrip strength and standing long jump (SLJ) tests, which represent the maximum handgrip strength and lower extremity explosive strength, respectively; (3) motor fitness was evaluated by a 2 × 10 m shuttle run test (10mSRT). Each child had two test attempts, except the 20mSRT, which was performed once. Meanwhile, children were given a break of 2 min between each test to wash out fatigue after the test. The greater scores of two attempts were used in data analysis. The detailed procedures of the physical fitness tests were described in the previous study[27].

Each fitness test data was transformed into standardized scores by Z-standardized value = (value-mean)/standard deviation (SD) due to the variables' different arithmetic scales and units. Since the Z-scores of 10mSRT were inversely linked with speed and agility performance, we multiplied the Z_{10mSRT} values by "-1". The composite Z-score of physical fitness was calculated as the mean of 4 individual Z-scores ($Z_{physical\ fitness} = (Z_{20mSRT} + Z_{grip} + Z_{SLJ} + Z_{10mSRT})/4$) and the $Z_{musculoskeletal\ fitness}$ was calculated as the mean of Z_{grip} values and Z_{SLJ} values. Then, the $Z_{physical\ fitness}$ was categorized into quartiles (Q1-Q4), with the highest quartile of $Z_{physical\ fitness}$ (Q4) was classified as high physical fitness and coded a value of "1" versus other quartiles (Q1-Q3) were classified as low physical fitness and coded a value of "0"[6]. High- and low-group scores were computed for Z_{20mSRT}, Z_{grip}, Z_{SLJ}, Z_{10mSRT}, and $Z_{musculoskeletal\ fitness}$ using the same procedures described for the physical fitness composite Z-score.

Statistical analysis

Descriptive characteristics are presented as means ± SDs and n (%) for continuous and categorical variables. No significant interactions were found between sex and age (all P>0.10), so we presented the data with the total sample. Differences among gender groups were explored by *t*-Tests. Meanwhile, differences among TPA/ST groups were explored by one-way ANOVA with LSD post hoc comparisons and Chi-square test for categorical variables.

Three steps explored associations among TPA, ST, and physical fitness. Firstly, binary logistic regressions were applied to explore the independent associations between TPA or ST and physical fitness components. Then, we ran linear regression analyses to explore the independent associations between TPA or ST and physical fitness composite Z-scores. We used three multivariate models to explore the independent associations between TPA or ST and physical fitness. Adjusted model [a] was adjusted for age, sex, BMI, and accelerometer wear time, adjusted model [b] was adjusted for model [a] and ST, and adjusted model [c] was adjusted for model [a] and TPA. Secondly, we entered 4 TPA/ST groups as the independent variable and the physical fitness components (20mSRT, handgrip,

Characteristics	All (n = 375)	Boys (n = 211)	Girls (n = 164)	*P* for sex
Age (months)	57.94 ± 5.44	58.35 ± 5.50	57.42 ± 5.32	0.121
Weight (Kg)	19.95 ± 3.29	20.64 ± 3.52	19.06 ± 2.73	< 0.001
Height (cm)	110.95 ± 4.96	111.63 ± 4.88	110.07 ± 4.92	0.005
Body mass index (Kg/m^2)	16.14 ± 1.87	16.48 ± 1.95	15.69 ± 1.66	< 0.001
VPA (min/day)	30.50 ± 9.86	31.92 ± 10.54	28.67 ± 8.61	0.004
MVPA (min/day)	69.60 ± 17.40	72.46 ± 18.34	65.94 ± 15.41	< 0.001
TPA (min/day)	163.05 ± 33.51	169.11 ± 34.12	155.24 ± 31.10	< 0.001
ST (min/day)	565.01 ± 76.46	559.66 ± 79.35	571.90 ± 72.22	0.197
20 m shuttle run (laps)	12.64 ± 4.72	12.43 ± 4.56	12.92 ± 4.92	0.318
Handgrip (kg)	6.55 ± 2.34	6.95 ± 2.33	6.04 ± 2.26	< 0.001
Standing long jump (cm)	84.16 ± 16.35	85.62 ± 16.51	82.27 ± 16.01	0.035
2 × 10 m shuttle run (s)	7.215 ± 0.81	7.17 ± 0.86	7.27 ± 0.75	0.094
Accelerometer wear time (min/day)	729.43 ± 87.10	734.00 ± 83.55	723.54 ± 91.39	0.406
Physical fitness composite Z-score	0.00 ± 0.76	0.00 ± 0.78	0.00 ± 0.74	0.747
High physical fitness (n, %)				
Yes	92 (24.53%)	51 (24.17%)	41 (25.00%)	
No	283 (75.47%)	160 (75.83%)	123 (75.00%)	

Table 1. Descriptive characteristics of the preschool children (N = 375). The data are expressed as means ± SDs. Abbreviations: VPA: vigorous physical activity; MVPA: moderate-to-vigorous physical activity; TPA: total physical activity; ST: sedentary time.

Comparison	Mean ± SD	*P* for groups
TPA (min/day)		
Low sedentary (n = 188)	159.01 ± 34.90	0.017*
High sedentary (n = 187)	167.11 ± 31.62	
ST (min/day)		
Low active (n = 255)	562.14 ± 81.04	0.381
High active (n = 120)	571.10 ± 65.55	

Table 2. Comparison of means ± SDs for TPA time in min/day stratified by as low- and high ST classification and ST min/day stratified by low- and high active classification (N = 375). The data are expressed as means ± SDs, **P* value < 0.05. Abbreviations: TPA: total physical activity; ST: sedentary time.

SLJ, musculoskeletal fitness, and 10mSRT) and physical fitness composite Z-score as dependent variables. And multinomial logistic regressions were fitted to explore the joint associations between TPA/ST groups, physical fitness components and physical fitness composite Z-score with the low active/high sedentary group as a reference. Additionally, we adjusted for relevant confounders like age, sex, BMI, and accelerometer wear time. Thirdly, the isotemporal substitution model was widely used to investigate the change of outcome when a daily movement behavior replaced by another behavior, and it was used as an effective model in epidemiological research[44]. In present study, this model was applied to explore the effect of reallocating 30 min/day TPA time with an equal duration of ST on physical fitness in preschooler, while remaining other daily movement behaviors time consistent (i.e., the new ST expression is: ST = mean ST + 30 (min/day), the new TPA expression is: TPA = mean TPA-30 (min/day)). To ensure the feasibility of allocating time (e.g., 30 min/day), we took the girl's minimum amount of 1 SD for TPA (e.g., 31.1 min/day) into consideration.

The data were presented as means ± SDs, odds ratios (ORs), and 95% confidence intervals (CIs) or βs and 95% CIs. All data analyses were performed using Empower (R) (www.empowerstats.com, X&Y Solutions, Inc., Boston, MA, USA) and R (http://www.R-project.org), with a significance level set as P<0.05.

Results

Table 1 shows the descriptive characteristics of the preschool children. In total, 8 characteristics of weight, height, BMI, VPA, MVPA, TPA, handgrip, and SLJ showed significantly higher scores in boys than girls (all P<0.05).

Table 2 presents the TPA min/day stratified by classification of time spent in sedentary behaviors (low- and high-sedentary) and the ST min/day stratified by classification of time spent in low- and high-TPA in preschool children. Differences in TPA min/day were observed between preschoolers classified as high- and low-sedentary (P < 0.05). No differences in ST were observed between preschoolers classified as high- and low-active (P > 0.05).

Table 3 shows the Preschooler's 10 characteristics by TPA/ST groups. Weight, height, VPA, MVPA, TPA, ST, handgrip, 10mSRT, accelerometer wear time, and the physical fitness composite Z-score differed significantly the 4 TPA/ST groups (all P<0.05). Group 2 had less ST and accelerometer wear time than group 1. Group 3 had

Characteristics	Low active		High active		P for groups
	High sedentary ($n = 120$) (Group 1)	Low sedentary ($n = 135$) (Group 2)	High sedentary ($n = 67$) (Group 3)	Low sedentary ($n = 53$) (Group 4)	
Age (months)	58.13 ± 5.59	57.33 ± 5.30	58.99 ± 5.48	57.76 ± 5.31	0.222
Weight (Kg)	19.59 ± 3.10	19.60 ± 3.26	20.91 ± 3.37 [b, c]	20.41 ± 3.47	0.007
Height (cm)	110.65 ± 4.55	110.30 ± 5.00	112.42 ± 4.88 [b, c]	111.42 ± 5.50	0.016
Body mass index (Kg/m^2)	15.96 ± 1.90	16.04 ± 1.93	16.49 ± 1.89	16.34 ± 1.56	0.220
VPA (min/day)	35.13 ± 7.00	34.30 ± 6.67	48.72 ± 6.83 [b, c]	48.20 ± 6.83 [d, e,f]	< 0.001
MVPA (min/day)	61.75 ± 11.67	60.67 ± 13.33	86.06 ± 11.64 [b, c]	89.35 ± 11.86 [d, e]	< 0.001
TPA (min/day)	148.82 ± 21.98	142.26 ± 24.19	199.85 ± 15.85 [b, c]	201.66 ± 16.99 [d, e]	< 0.001
ST (min/day)	627.41 ± 39.22	504.13 ± 62.28 [a]	615.52 ± 36.58 [c]	514.94 ± 48.76 [d, f]	< 0.001
20 m shuttle run (laps)	12.64 ± 4.89	12.21 ± 4.58	12.87 ± 4.77	13.47 ± 4.63	0.110
Handgrip (kg)	6.18 ± 2.33	6.34 ± 2.16	7.23 ± 2.27 [b, c]	7.06 ± 2.68 [d]	0.010
Standing long jump (cm)	82.61 ± 15.12	84.06 ± 16.17	85.30 ± 18.88	86.49 ± 16.16	0.286
2 × 10 m shuttle run (s)	7.30 ± 0.74	7.30 ± 0.82	7.06 ± 0.99	7.00 ± 0.62 [d, e]	0.002
Accelerometer wear time (min/day)	770.38 ± 57.23	658.40 ± 69.76 [a]	810.82 ± 54.04 [b, c]	714.73 ± 71.37 [d, e,f]	< 0.001
Physical fitness composite Z-score	-0.08 ± 0.72	-0.07 ± 0.75	0.13 ± 0.85	0.19 ± 0.73 [d, e]	0.012
High physical fitness (n, %)					
Yes	24 (20.00%)	28 (20.74%)	22 (32.84%)	18 (33.96%)	
No	96 (80.00%)	107 (79.26%)	45 (67.16%)	35 (60.04%)	

Table 3. Descriptive characteristics of the preschool children ($N = 375$). The data are expressed as means ± SDs. [a] Group 2 versus Group 1, $P<0.05$; [b] Group 3 versus Group 1, $P<0.05$; [c] Group 3 versus Group 2, $P<0.05$; [d] Group 4 versus Group 1, $P<0.05$; [e] Group 4 versus Group 2, $P<0.05$; [f] Group 4 versus Group 3, $P<0.05$. Abbreviations: VPA: vigorous physical activity; MVPA: moderate-to-vigorous physical activity; TPA: total physical activity; ST: sedentary time.

higher weight and height measures, more VPA, MVPA, and TPA time, higher handgrip strength scores, and more accelerometer wear time than groups 1 and 2. Group 3 also had a more ST than group 2. Group 4 had less ST than groups 1 and 3, more VPA, MVPA, and TPA time, and a higher physical fitness composite Z-score than group 1 and 2. Time in VPA was less in group 4 than in group 3. Handgrip strength scores were higher in group 4 than group 1, and the 10mSRT score was faster in group 4 than in groups 1 and 2. Group 4 also had less accelerometer wear time than groups 1 and 3, but more than group 2. Most preschool children were classified as high active/low sedentary (33.96%) and high active/high sedentary (32.84%). Fewer children were classified as low active/high sedentary (20%), and low active/low sedentary (20.74%).

Table 4 shows the independent associations of TPA time and ST with physical fitness components and the physical fitness composite Z-score. After controlling for ST, age, sex, BMI, and accelerometer wear time, the time spent in TPA was positively associated with a high level of CRF, handgrip strength, SLJ, musculoskeletal fitness, and the physical fitness composite Z-score. However, these associations were low and not appreciably different from null findings. ST showed no association with the physical fitness characteristics and the physical fitness composite Z-score after controlling for TPA, age, sex, BMI, and accelerometer wear time.

Table 5 presents ORs, B values, and 95% CIs for the joint associations of TPA/ST with physical fitness characteristics and the physical fitness composite Z-score in preschool children. The referent group is low active/high sedentary. After controlling for age, sex, BMI, and accelerometer wear time, preschool children in high active/low sedentary and high active/high sedentary groups were likelier to achieve a high level of handgrip strength than the high active/high sedentary and referent groups. The high active/low sedentary and low active/low sedentary were more likely to achieve a high level of musculoskeletal fitness than the high active/high sedentary and referent groups. The probability of achieving a high physical fitness composite Z-score level increased by 30% (β, 0.30; 95% CI, 0.07, 0.54) for classification in the high active/low sedentary group.

Table 6 shows the isotemporal substitution showing that replacing 30 min/day of TPA time with 30 min/day of ST decreased the probability of achieving a high physical fitness composite Z-score by 15% (β, -0.15; 95% CI, -0.05, -0.00), after controlling for the age, sex, BMI and accelerometer wear time.

Discussion

The primary finding of this study was that more time spent on TPA and less time spent on sedentary behaviors is positively related to higher levels of physical fitness and several of its characteristic scores (20mSRT and musculoskeletal fitness) in preschool children. Favorable associations were observed between the high active/low sedentary group and the high active/high sedentary group with handgrip strength. Low active/low sedentary group status and high active/low sedentary group status were positively associated with musculoskeletal fitness. Only the high active/low sedentary group was associated with the physical fitness composite Z-score. After adjusting for age, sex, BMI, and accelerometer wear time, TPA was weakly and ST was not independently related to the physical fitness domains and the physical fitness composite Z-score. Using isotemporal substitution,

Physical fitness components	TPA		ST	
	Adjusted model [a]	Adjusted model [b]	Adjusted model [a]	Adjusted model [c]
20 m shuttle run [d]				
Low level ($n = 282$)	Ref.	Ref.	Ref.	Ref.
High level ($n = 93$)	1.02 (1.01, 1.03) ***	1.02 (1.01, 1.03) ***	1.00 (0.99, 1.00)	1.00 (0.99, 1.01)
Musculoskeletal fitness [d]				
Handgrip low level ($n = 281$)	Ref.	Ref.	Ref.	Ref.
Handgrip high level ($n = 94$)	1.01 (1.01, 1.02) **	1.01 (1.01, 1.02) **	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Standing long jump low level ($n = 282$)	Ref.	Ref.	Ref.	Ref.
Standing long jump high level ($n = 93$)	1.01 (1.00, 1.02) *	1.01 (1.00, 1.02) *	1.00 (1.00, 1.00)	1.00 (0.99, 1.00)
Musculoskeletal fitness low level ($n = 282$)	Ref.	Ref.	Ref.	Ref.
Musculoskeletal fitness high level ($n = 93$)	1.02 (1.01, 1.03) ***	1.02 (1.01, 1.03) ***	0.99 (0.99, 1.00) *	1.00 (0.99, 1.00)
2 × 10 m shuttle run [d]				
Low level ($n = 282$)	Ref.	Ref.	Ref.	Ref.
High level ($n = 93$)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Physical fitness composite Z-score [e]	0.01 (0.00, 0.01) ***	0.01 (0.00, 0.01) ***	-0.00 (-0.00, 0.00)	-0.00 (-0.00, 0.00)

Table 4. ORs and the 95% CIs for the independent associations of TPA- and ST with high- and low- categories for the physical fitness characteristics and the physical fitness composite Z-score in preschool children ($n = 375$). [a] Models were adjusted for age (months), sex, body mass index (kg/m^2) and accelerometer wear time (min/day); [b] Models were adjusted for age (months), sex, body mass index (kg/m^2), accelerometer wear time (min/day) and ST (min/day); [c] Models were adjusted for age (months), sex, body mass index (kg/m^2) and accelerometer wear time (min/day) and TPA (min/day); [d] data are expressed as ORs and 95% CIs; [e] data are expressed as βs and 95%. CIs. * P Value < 0.05; ** P Value < 0.01; *** P Value < 0.001. Abbreviations: TPA: total physical activity; ST: sedentary time.

Physical fitness characteristics	Low active/ High sedentary ($n = 120$) (Referent)	Low active/ Low sedentary [a] ($n = 135$)	High active/ High sedentary [a] ($n = 67$)	High active/ Low sedentary [a] ($n = 53$)
20 m shuttle run [b] ($n = 375$)	1.0	0.73 (0.35, 1.55)	1.52 (0.74, 3.14)	1.77 (0.82, 3.83)
Handgrip [b] ($n = 375$)	1.0	1.38 (0.63, 3.01)	2.29 (1.09, 4.80) *	3.50 (1.59, 7.70) **
Standing long jump [b] ($n = 375$)	1.0	1.22 (0.58, 2.55)	1.56 (0.75, 3.24)	1.65 (0.75, 3.66)
Musculoskeletal fitness [b] ($n = 375$)	1.0	2.25 (1.01, 5.02) *	1.96 (0.91, 4.21)	4.09 (1.82, 9.22) ***
2 × 10 m shuttle run [b] ($n = 375$)	1.0	1.61 (0.78, 3.31)	1.87 (0.92, 3.82)	0.95 (0.40, 2.23)
Physical fitness composite Z-score [c] ($n = 375$)	1.0	0.04 (-0.17, 0.26)	0.20 (-0.02, 0.41)	0.30 (0.07, 0.54) *

Table 5. ORs, β values and 95% CIs for the odds of higher physical fitness characteristic scores by combinations of PA and sedentary time in preschool children ($n = 375$). [a] Models were adjusted for age (months), sex, body mass index (kg/m^2) and accelerometer wear time (min/day); [b] data are expressed as ORs and 95% CIs; [c] data are expressed as βs and 95% CIs; * P Value < 0.05; ** P Value < 0.01; *** P Value < 0.001.

Physical fitness composite Z-score	β (95% CI)	P Value
Model (replace 30 min of TPA) [a]	-0.15 (-0.05, -0.00)	0.029

Table 6. Isotemporal substitution of 30 min of TPA with 30 min of ST on the physical fitness composite Z-score in preschool children ($n = 375$). Data are expressed as βs and 95% CIs. [a] Model was adjusted for age (months), sex, body mass index (kg/m^2), accelerometer wear time (min/day) and TPA.

replacing 30 min of TPA with equal time in sedentary behavior reduced the probability of having a high physical fitness composite Z-score by 15%.

Previous longitudinal studies observed that MVPA is positively associated with physical fitness composite scores[41]. Musculoskeletal and motor fitness are the foundation of motor skills, and a longitudinal study revealed that preschool children with more baseline PA were related to favorable motor skills and CRF improvements over 9 months[45]. Moreover, Kriemler and colleagues found that lifestyle interventions, including a playful PA program, provided promising effects for preschool children on physical fitness regardless of overweight or low fitness status[46]. Overall physical fitness, reflected by the physical fitness composite Z-score in this study, is a positive health marker in young children[1]. However, while the independent associations between the TPA time and physical fitness characteristics scores or the physical fitness composite Z-score were statistically significant, they were low (Table 4). This finding differs from prior studies reporting positive associations between higher amounts of TPA and physical fitness measures in young children[41,45,46]. One possible reason for lack of strong association could be explained by the small unit of TPA (min/day), if we enlarge the unit into 10 min/day, the effects between TPA and physical fitness will be larger. Another possible reason is the similar time spent in TPA within the low- and high-sedentary groups (Table 2) diminishing differences, 159.01 ± 34.90 min/day of TPA in the low-sedentary group is not much different with 167.11 ± 31.62 min/day in the high-sedentary group.

Previous studies on the associations between ST and physical fitness have shown inconsistent and inconclusive results. For instance, and Leppänen et al.[41] found that time spent in sedentary behaviors had no association with physical fitness characteristics. At the same time, similar researchers have shown an inverse association between ST and physical fitness[8,47]. Our results align with Leppänen et al.[41], who show no association between ST and physical fitness in young children. However, other researchers observed negative associations between ST and physical fitness domains in children and adolescents[23,24]. The inconsistent and inconclusive associations between time spent in sedentary behaviors and physical fitness scores may be explained as follows. Firstly, different tools were applied for ST measurement (e.g., questionnaires, parental reports[48] or objectively measured accelerometers[49]. Sarker and coworkers reported a big difference between subjectively and objectively ST measurement, and the latter was closer to the practical value[50]. Secondly, different parameter settings are employed in ST measurement. The data inclusion criteria, such as participants with valid days of at least 3 days[48] or 1 day[51] between studies. Thirdly, preschoolers' activity and sedentary behavior are sporadic and intermittent essentially, and frequent breaks take place in their sedentary behavior. One publication by our research team reported that the total ST and ST bouts times negatively associated with physical fitness, but the ST breaks frequency positively associated with physical fitness[9]. Hence, we speculate that the null association between ST and physical fitness in our study may be due to the high level of ST breaks times. Nevertheless, the children and adolescents' sedentary behaviors are prolonged, and that's why researchers observed consistent negative association between ST and physical fitness domains in this population. Fourthly, participants in the null association studies did not achieve the sedentary duration threshold to influence a physical fitness decline. Leppänen et al.[41] reported null association between ST and physical fitness in preschool children; however, when they used isotemporal substitution of 5 min/day of vigorous PA for 5 min/day of ST, the association between ST and physical fitness became positive and statistically significant. We used isotemporal substitution to replace 30 min/day of TPA with 30 min/day of ST (Table 5). As expected, the association between increased ST/day and reduced physical fitness was statistically significant. Last but not the least, measurement error may contribute to our study's null independent association between ST and physical fitness. We applied 100 CPM cut points for ST measuring, since there is no consensus regarding to data processing at present in preschool children[52,53]. Trost et al.[54] reported compared to direct observation, cut points range from ≤ 100 CPM to ≤ 1488 CPM overestimated ST range from 6.3 min to 13.1 min[54]. Therefore, the use of the 100 CPM threshold for sedentary behavior may be the most practical choice among preschoolers[54], and it is also wildly validated and used by peer publications[54–56]. The ability to accurately convert the accelerometer output into standard outcomes is important for all aspects of pediatric ST research, and more precise preschooler cut-off point testing is required to reach consensus on the most appropriate cut-off points for researchers to apply.

This study explored the joint associations between PA and ST with physical fitness in Chinese preschool children ages 3 to 6 years. We showed that young children in the high active/low sedentary group had higher odds of having high physical fitness levels than children in the low active/high sedentary group. Other positive associations between joint levels of PA and ST with physical fitness were reported in Table 5. These findings demonstrate the importance of young children engaging in more PA and decreasing ST to maintain high physical fitness levels, achieve better health, and lower risks of chronic diseases. Further, it shows the importance of addressing two different constructs concurrently, TPA and ST, given that independent associations between TPA and ST were not associated with physical fitness in this study. These findings highlight the importance of lifestyle behaviors, TPA, and ST health promotion programs in this age group. Additionally, compositional and isotemporal reallocation studies reported joint associations of increasing MVPA and reducing an equal duration of ST were favorable to preschooler's CRF[57] and muscular strength after including relative covariates[58], our results are consistent with former studies. One reason of high active/low sedentary group achieving the high physical fitness level could be explained that this group had higher VPA level than groups of low active/high sedentary and low active/low sedentary. And high intensity PA is associated with muscle strength, aerobic fitness and motor fitness improvement in preschoolers[42]. Since we only employed the TPA in present study, further studies with different types of PA (e.g., MVPA, VPA) should be take into consideration to strengthen the evidence on the relationship between PA, ST and physical fitness domains, physical fitness component Z-scores, and health outcomes in preschool children to understand better behaviors associated with health outcomes. Besides, though we took some sociodemographic confounders into consideration in our analyses, preschoolers' fitness is impacted by many factors such as socioeconomic status, environment, and dietary habits, future studies should take other confounders into consideration (e.g., family support, eating behavior, sleep behavior).

To our knowledge, this is the first study to measure the independent and joint associations between TPA and ST with physical fitness in Chinese preschool children. Whereas independent associations between TPA and ST with physical fitness outcomes were not statistically significant, we confirmed the importance of engaging in TPA and reducing ST using an isotemporal substitution paradigm, showing that replacing TPA time with ST reduced the physical fitness composite Z-score. However, the cross-sectional study design prohibits confirmation of causality in our findings, since we cannot draw the conclusion that increasing PA and reducing ST improving the high physical fitness level or high level of physical fitness participants seemed to attend more PA and less ST. Further studies with a longitudinal design could provide more definitive conclusion. Also, we enrolled a convenience sample of preschool children living in northeast Shanghai, increasing the risk of selection bias. This sampling strategy limits the generalizability of the study findings to preschool children from different areas. Compared with underdeveloped areas, shanghai, a region with prosperous economy may create more opportunities and encourage preschoolers to engage in more PA. Additionally, its favorable climates may also prompt preschoolers to participate in more PA than cold region. Larger sample sizes with a wide variation in TPA and ST are warranted to identify associations with physical fitness in further studies.

With regarding to the accelerometers, there are several limitations should be point out. The accelerometers we applied are not able to capture water-based activities and upper body activities, which may to some extent underestimated the PA levels, but data in present study shown PA is significantly associated with physical fitness, and if we add the underestimated PA levels, the association will remain consistent. Therefore, it doesn't much matter with the results biases. Meanwhile, this device is not able to identify different types of sedentary behavior, posture and posture transitions (i.e., sitting, standing, and lying down, screen-based or non-screen sedentary behaviors), which may lead to different health implications[52]. Applying multi-unit monitors may offset this limitation, but accelerometer is the most appropriate and standard tool at present[52].

Conclusion

Increased time in TPA and less time/day in ST is associated with a higher physical fitness composite Z-score in Chinese preschool children. Replacing 30-minutes/day of TPA with 30-minutes/day of ST reduced physical fitness scores. Additional studies are needed to confirm these findings in Chinese preschool children. Policymakers, parents, and preschool teachers should focus on settings encouraging preschool children to increase TPA and reduce ST.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

CF and MQ conceived and designed the study. CF, LL, CH, FL and XY helped with data collection, analysis and interpretation. CF, JZ, YL and MQ: drafting the article or revising it critically for important contents. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics statement
This study was reviewed and approved by the Ethics Committee of Shanghai University of Sport (ethic committee code:2015028).

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